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Effect of integrated nutrient management on some physical properties of soil under poplar based agroforestry system in Himalayan foothills, India

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Abstract
A field experiment was conducted to assess the effect of integrated nutrient management on some physical properties of soil in wheat (*Triticum aestivum* L.) crop on Mollisols of Uttarakhand under poplar based agroforestry at Agroforestry Research Centre (old site), Patharchatta of G.B. Pant University of Agriculture and Technology, Pantnagar during rabi seasons of 2017-19. The experiment was laid in Randomized Complete Block Design comprising of nine nutrient treatments (chemical fertilizers and its substitution with organics) replicated thrice. Bulk density was recorded minimum under T_5 (1.31 Mg m^{-3}) management while it was recorded high with soil depth and with control treatments. Owing to a negative relationship between bulk density and water holding capacity, T_5 subsequently had significantly maximum values of both soil water holding capacity (72.1%) as well as hydraulic conductivity (0.74 cm hr^{-1}) in 0-15 cm soil layer. Usage of organic sources with fertilizers improved the physical properties of soil after two years of continuous nutrient application.

Keywords: Integrated nutrient management, bulk density, vermicompost, hydraulic conductivity, agroforestry

Introduction

The projection for 2025 for Indian population growth is expected to be 1.33 billion which may eventually reach a staggering 1.6 billion by the year 2050 (Hajer *et al*., 2015) [7]. The Indian food grain demand will be around 293 million tonnes by 2030 as reported by Berners-Lee *et al*., 2018 [3] which will further rise up to 339 million tonnes by 2040. Productivity of most crops has come to a decline or had become stagnant in the past few years. One of the primary reasons for such low productivity even under well irrigated conditions are the deficient and disproportioned usage of chemical inputs (Lotter, 2003) [12], paucity of secondary and micronutrient availability and poor soil organic carbon (SOC) content that has lead to substandard soil health (Swarup *et al*., 2000 and Yadav *et al*., 2016) [21, 22] further aggravated in countries like India. Long term experiments have revealed that sole application of chemical fertilizers to supply plant nutrition can deplete soil organic matter content, resulting in diminished soil productivity (Sharma *et al*., 2015, Srivastava, 2016 and Jat *et al*., 2018) [19, 20, 8]. It optimizes all aspects of nutrient cycling including N, P, K and other macro and micronutrient inputs and outputs, with the aims of synchronizing nutrient demand by the crop and its release in the environment. Under INM practices, the losses through leaching, runoff, volatilization, emissions and immobilization are minimized, while high nutrient use efficiency is achieved (Zhang *et al*., 2004) [23]. Moreover, it also aims to optimize the soil conditions by improving its physical, chemical, biological and hydrological properties to enhance farm productivity and minimize land degradation (Jones and Donnelly, 2004) [9]. After its emergence as a scientifically recognized discipline and practice, the ability of agroforestry to improve the soil quality has been widely recognized as a major advantage (Campbell *et al*., 2000) [6]. Incorporation of trees in agroforestry enhances the soil organic matter by adding litter both above and below ground. Therefore, integrated nutrient management and agroforestry land use system are among the best solutions for the ever escalating price and scarcity of chemical fertilizers for small holding farmers in developing countries. Therefore, this approach will go a long way in building land productivity since the system will provision for almost all nutrients in a judicious way.

Materials and Methods
The present investigation was carried out during *rabi* seasons of 201719. The research involved assessment of the effects on soil physical properties of combined usage of organic and inorganic nutrient sources for two years. The field trial was carried out at experimental site of Agroforestry Research Centre (old site) near Horticulture Research Centre, Patharchatta of G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, Uttararakhand. The centre at Pantnagar is in the *Tarai* region located between 28°58' N to 29° 1' N Latitude and 79° 24' E to 79° 31' E longitudes and at an altitude of 243.84 meters above the mean sea level. The *Tarai* is a lowland area situated in northwestern India, a part of the southern foothills of the Himalayas, the Siwalik Mountains, and north of the Indo-Gangetic plain. This belt of lowlands is distinguished by dense grasslands, savannah, sal woods and deep rich clay swamps. The average annual temperature is 23.25 °C. Maximum temperature of about 37.26 °C is observed in May and varies between 19.62 and 37.26 °C.The coldest month is considered to be January (6.44 °C), and the minimum temperature ranges between 6.44 and 25.40 °C (July). The mean annual rainfall is around 1581.45 mm, of which 80-90 per cent is received between June and September. The soil of the experimental site belonged to Makota-III clay loam as surface texture, neutral in reaction, low in nitrogen, medium in available phosphorus and potassium but high in organic carbon. The experiment was laid out in Randomized Block Design replicated thrice with nine treatments *viz.* T_1 (Open Control), T_2 (Control under poplar agroforestry), T_3 (100% RDF), T_4 (100% RDN through FYM), T_5 (100% RDN through VC), T_6 (50% RDN through FYM + 50% RDN through urea), T_7 (50% RDN through VC + 50% RDN through urea), T_8 (50% RDN through FYM + 50% RDN through VC) and T_9 (50% RDN through organics (25% FYM + 25% VC) + 50% RDN through urea). The soil samples of desired depths (0-15 and 15-30 cm) were obtained from each experimental plots by core method. The volume of soil and mass of oven dry soil were determined. Bulk density was calculated as the ratio of mass of soil to its total volume (Blake and Hartge, 1986) [5] and soil water holding capacity was determined using Hilgard apparatus (Piper, 1950) [13]. Air dry processed soil was uniformly packed in the keen box lined with filter paper. After filling the boxes, the dry weight was taken. Soil was saturated from below by water kept below these boxes on the tray for about 12 hrs. Then the moist weight was taken and the soil was dried in oven for 24 hrs at 105 ^{0}C. Determination of hydraulic conductivity was obtained by constant head method (Klute, 1965) [11].

Results and Discussion
Bulk density (BD)
The data (Table 1) showed that all treatments had a significant effect in reducing BD in subsurface soil over open control. T_5 was observed to be significantly maximum in reducing soil BD in both layers compared to application of other treatments. T_5 reduced BD over T_1 by 6% and 5.7% in both layers. Application of T_4 was statistically seen to be at par to application of T_6 and conjoined use of T_9 in 0-15 cm. However, in 15-30 cm T_4 and T_8 use produced at par results. It was clearly revealed that the bulk density of sub surface was higher than the surface soil.

Table 1: Effect of integrated nutrient management on soil bulk density (Mg m^{-3})

Treatment	Soil bulk density (Mg m^{-3}) pooled	
	0-15 cm	15-30 cm
T_1	1.39	1.46
T_2	1.37	1.44
T_3	1.36	1.42
T_4	1.35	1.40
T_5	1.31	1.38
T_6	1.35	1.41
T_7	1.32	1.40
T_8	1.34	1.40
T_9	1.35	1.41
SE(m) ±	0.01	0.01
C.D. (5%)	0.03	0.04

The decline in bulk density over the years could be attributable to the incorporation of root and plant biomass and the transfer of some micro pores to macropores induced by the cementing action of organic acids and polysaccharides produced by higher microbial activities during the decomposition of organic residues Regardless of the depths of the surface, the control plot displayed always higher bulk density. Selvi *et al.*, (2005) [18] reported that due to increased organic matter addition through enhanced plant biomass production the bulk density of plots receiving only chemical fertilizers was lowered. Due to the addition of FYM along with NPK the decrease in bulk density was also recorded elsewhere (Premi, 2003 and Sarkar *et al*., 2003) [14, 17]. Several resistant products were produced during the decomposition of organic manures, often fostering microbial activity which could increase the amount of polysaccharide and microbial gum synthesis. Such compounds serve as a binding agent and aid in the accumulation of soil which could lead to a reduction of bulk density. Sarkar *et al*. (1997) [16] have reported similar findings. The bulk density generally increases with soil depth rises (Rudrappa *et al*., 2006) [15]. Subsurface soil's higher bulk density relative to surface soil may be due to higher subsurface compaction and higher organic carbon, higher root biomass production with surface nutrient application.

Water holding capacity (WHC)
In Fig. 1, the WHC of T_5 was increased by 19.4% over T_1 followed by T8 (15.1%). In subsurface layer, T_5 increased by 29.8% over T1. Also T_5 was significantly highest in surface layer while it was at par to T_8 in deeper layer. On applying sole manures in 15–30 cm layer, all three organic applications (T_4, T_5 and T_8) were statistically at par to each other.

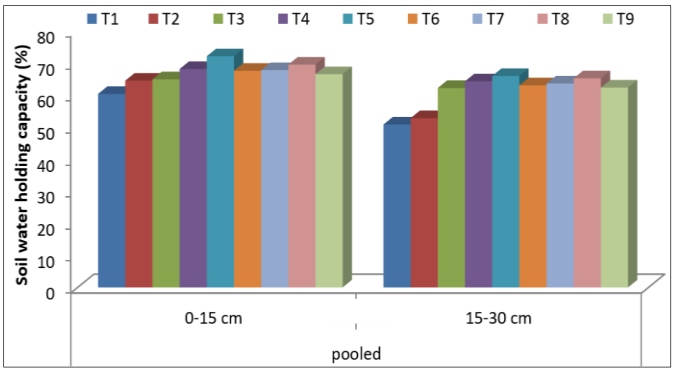

Fig 1: Effect of integrated nutrient management on soil water holding capacity (%)

Selvi *et al*. (2005) [18] found that water holding capacity in the plots of 100 percent NPK + FYM application was the maximum in the long term fertilizer experiment. In addition, they indicated that higher water holding capacity of the added organic matter may have improved the soil's water holding efficiency. In FYM treated plots, the higher SOC content may be responsible for growing the soil's WHC, with the change becoming more noticeable in the soil surface layers. The higher WHC in the surface layers may be attributed to surface application of FYM, whereas the rise in WHC in the subsurface layers may be due to the increased root biomass with FYM or inorganic fertilizers.

Due to negative relationship between BD and WHC, greater organic matter in the surface soil with decreased soil BD increased WHC (Bandyopadhyay *et al*., 2010) [2].

Hydraulic conductivity (HC)

Significantly lowest hydraulic conductivity was recorded in control treatments (T_1 and T_2) compared to nutrient treatments. In Fig. 2, in 0-15cm, it revealed that among integrated treatments, T_5 was the best followed by T_8 over T_1 by 19.3% and 17.7% respectively, T_6 and T_7 were statistically at par with each other. Among sole organics, T_8, T_5 and T_4 were at par with each other. Application of T_4 was significantly better than T_3. In subsurface depth, the trend observed was $T_5 > T_8 > T_4 > T_7 > T_6 > T_9 > T_3 > T_2 > T_1$. T_6, T_7 and T_8 were at par with each other but T_5 was significantly superior over all nutrient treatment combinations. T_4 and T_8 were at par to one another but were superior to T_3.

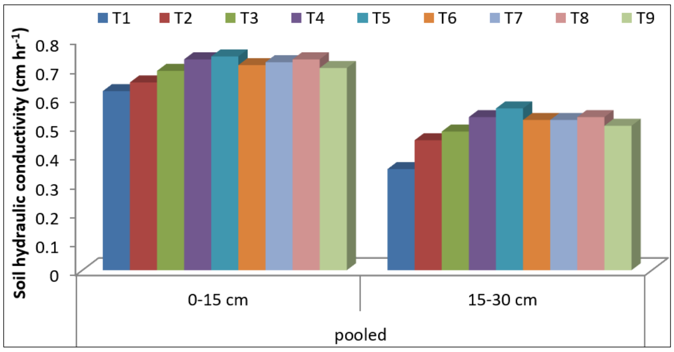

Fig 2: Effect of integrated nutrient management on soil hydraulic conductivity (cm hr^{-1})

Improving saturated hydraulic conductivity with FYM application may be due to increased organic soil carbon content, which improved soil accumulation, decreased bulk density, and increased overall porosity. Katkar *et al*., (2011) [10] also stated that the HC increased through direct application of organic matter through FYM. Relatively higher saturated hydraulic conductivity was reported in the upper layer of soil than in the lower layer, which could result in increased lower layer compaction (Ali *et al*., 2012) [1]. Similar to the subsurface soils, the surface soil with comparatively higher organic matter content was less compact, which may have contributed to easier water passage through the surface layer.

Higher K_{sat} values may be due to an improvement in pores type, continuity, and structure (Bhattacharyya *et al*., 2008) [4]; as in this study, the pores of transmission were substantially more abundant in those treatments. Manure treatments greatly improved soil structural stability and biological activity, enhancing efficient pore volume and improving connectivity, thus increasing K_{sat}.

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